Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

Circular No. 578

November 1940 • Washington, D. C.

UNITED STATES DEPARTMENT OF AGRICULTURE

Production and Agricultural Use of Ammonium Sulfate[1]

By C. C. **Fletcher**, formerly *associate chemist, Division of Soil Fertility Investigations*, **Albert R. Merz**, *chemist, Division of Fertilizer Research*, and **B. E. Brown**, *senior biochemist, Division of Soil Fertility Investigations, Bureau of Plant Industry*

CONTENTS

	Page
Introduction	1
Byproduct ammonium sulfate	2
Synthetic ammonium sulfate	2
Production, import, and export statistics	3
Composition	3
Cost of nitrogen in nitrogenous fertilizer materials	4
Ammonium sulfate in relation to crop production	5
Nitrogen an essential plant-food element	5
Properties of ammonium sulfate in relation to the soil	6
Residual effects of ammonium sulfate on crop growth	7
Agricultural uses of ammonium sulfate	7
Application to soil	7
Ammonium sulfate in relation to crop production—Continued.	
Soil bacteria	8
Ammonium sulfate in mixtures	8
Proper use of ammonium sulfate	9
Methods of applying ammonium sulfate	9
Use on individual crops	10
Quality of crops	11
Use in gardens	11
Special uses for ammonium sulfate	12
For greenhouse crops	12
For lawns	12
Home mixing	12
Preparation of composts from waste materials	14

INTRODUCTION

Ammonium sulfate, commonly known in the fertilizer trade and by farmers as sulfate of ammonia, is more extensively used than any other nitrogenous fertilizer material. It is one of the outstanding sources of available nitrogen for plants and has been used as a fertilizer material in the United States for a long time. Recognition of its value for the production of crops has resulted from a great deal of experimental work and from the experience of farmers and gardeners. Unlike sodium nitrate, large natural deposits of which are located in Chile, ammonium sulfate has been found in only very small quantities about volcanoes and in the guano on the Guanape

---

[1] This publication presents general information concerning the production and agricultural use of ammonium sulfate. No special attempt has been made to offer specific recommendations as to time, rate, and methods of application for different localities wherein the soils may vary considerably in texture and composition. In addition, the nitrogen requirement of different crops will vary somewhat in accordance with their character of growth. For these reasons specific information concerning the use of ammonium sulfate is best obtained from State agricultural experiment stations, county agents, or the United States Department of Agriculture.

Islands off the coast of Peru. It is obtained commercially, therefore, solely as a manufactured product.

BYPRODUCT AMMONIUM SULFATE

Ammonium sulfate is produced on a large scale as a byproduct of the iron and steel industry in connection with the manufacture of coke for use in blast furnaces. The coke is made from bituminous coal, which is of vegetable origin and contains a part of the nitrogen that was present in the original plants from which the coal has been derived. In the coking process, the nitrogen of the coal is converted in part to ammonia, which is carried along with the other gases that are evolved in the process. In the old-fashioned beehive coke ovens these gases for the most part burn as they escape from the oven without being utilized otherwise than to furnish the heat necessary for the coking. In modern byproduct coke ovens or retorts, however, the gases serve as the source of many valuable commercial products. The ammonia they contain is ordinarily removed by passing the gases through sulfuric acid in vessels known as saturators. The ammonia combines with the sulfuric acid to form ammonium sulfate that gradually accumulates in the sulfuric acid solution until, upon saturation of the solution therewith, crystals of ammonium sulfate form. The crystals are then separated from the liquor by means of centrifugal machines, and washed and dried. An average of about 22 pounds of ammonium sulfate is obtained per ton of coal used.

Ammonium sulfate is also obtained in comparatively small quantities as a byproduct in the coal-gas industry, in which the bituminous coal is subjected to a coking process primarily for the production of gas, and in the shale-oil industry, in which bituminous shales are distilled in retorts for the production of oil. In these industries, the ammonia is ordinarily first recovered from the gases as an ammoniacal liquor, which contains both free ammonia and ammonium salts dissolved in water that has been used to wash the gases, and the ammonia is then distilled from this "gas-liquor" to be subsequently absorbed in sulfuric acid and crystallized in a manner similar to that described above.

SYNTHETIC AMMONIUM SULFATE

Since the introduction of the synthetic-ammonia process for the fixation of atmospheric nitrogen, in which nitrogen from the air is caused to combine with hydrogen to form ammonia, ammonium sulfate has also been produced in large quantities by the absorption of the synthetically produced ammonia in sulfuric acid, the procedure used being essentially the same as that for the production of byproduct ammonium sulfate. Ammonia that has been obtained from calcium cyanamide by treatment with steam is similarly used to produce ammonium sulfate.

In Germany, France, and England, however, a method has been employed that avoids the use, and consequently the cost of manufacture, of the sulfuric acid. In this process, finely ground gypsum or anhydrite, which are forms of calcium sulfate that are found in large natural deposits, is kept in suspension in water by means of agitation, and ammonia and carbon dioxide are both forced into the slurry to react with the calcium sulfate to form calcium carbonate and ammonium sulfate. The solid calcium carbonate is filtered off from the solution of ammonium sulfate, which is then evaporated to crystallize out the ammonium sulfate for subsequent separation by means of centrifugal machines.

Practically all the ammonium sulfate that is manufactured is employed for fertilizer purposes. It has also been used for the production of other ammonium salts and ammonia.

PRODUCTION, IMPORT, AND EXPORT STATISTICS

The production of ammonium sulfate at byproduct coke-oven plants since 1901 is given in the following tabulation:

Year	*Short tons*	*Year*	*Short tons*
1901	6, 500	1921	246, 300
1902	5, 600	1922	347, 800
1903	6, 200	1923	458, 000
1904	14, 100	1924	446, 600
1905	19, 300	1925	508, 500
1906	24, 000	1926	583, 900
1907	24, 400	1927	608, 100
1908	21, 400	1928	694, 000
1909	30, 100	1929	744, 200
1910	35, 100	1930	671, 000
1911	36, 500	1931	491, 800
1912	47, 700	1932	287, 600
1913	86, 700	1933	339, 300
1914	85, 400	1934	392, 700
1915	100, 000	1935	461, 800
1916	136, 000	1936	599, 800
1917	176, 400	1937	644, 870
1918	218, 200	1938	436, 932
1919	272, 200	1939	580, 274
1920	338, 000		

Table 1 gives the quantities of ammonium sulfate that have been imported into and exported from the United States annually since 1920.

TABLE 1.—*Imports and domestic exports of ammonium sulfate*

Year	Imported	Exported	Year	Imported	Exported
	Short tons	*Short tons*		*Short tons*	*Short tons*
1920	2, 233	[1] 66, 714	1930	37, 838	91, 461
1921	5, 238	114, 928	1931	127, 999	74, 930
1922	5, 477	165, 011	1932	344, 188	16, 511
1923	3, 964	172, 118	1933	393, 404	15, 968
1924	6, 720	132, 571	1934	207, 537	28, 704
1925	26, 613	137, 918	1935	88, 549	87, 837
1926	9, 392	202, 860	1936	171, 666	118, 476
1927	19, 211	155, 335	1937	93, 396	82, 786
1928	47, 114	104, 177	1938	135, 337	34, 402
1929	21, 069	162, 132			

[1] Exports for 8 months only, beginning May 1, 1920.

COMPOSITION

Pure dry ammonium sulfate contains 21.20 percent of nitrogen. Commercial ammonium sulfate, however, usually contains small quantities of moisture-free sulfuric acid and other substances that slightly reduce the nitrogen content; it is, therefore, sold under guarantees to have nitrogen contents that range from 20 to 21 percent, although most guarantees are of 20.50 or of 20.56 percent. The moisture content varies from a few tenths of 1 percent to about 2 percent. Ammonium sulfate that has been made by the absorption of ammonia in sulfuric acid regularly contains a small quantity of free sulfuric acid that seldom amounts to so much as 0.5 percent and as a rule is less than 0.2 percent. When the acid is neutralized and the material then dried and screened to remove lumps, a product of excellent physical condition, that permits of uniform distribution when applied to the soil and of satisfactory blending with other fertilizer materials, is obtained. Byproduct ammonium sulfate may also contain minute amounts of tarry matter, pyridine, cyanides, and other substances that are produced in the coking process, and iron derived from the apparatus in which it is made. These substances may impart yellowish, brownish, or other tints to the normally white product. Ammonium sulfate that has been produced by use of gypsum or anhydrite contains no free sulfuric acid.

In addition to its fairly high content of nitrogen, ammonium sulfate contains approximately 24 percent of the element sulfur, which is a partial insurance against a deficiency of this element developing in soils where intensive production is practiced.

COST OF NITROGEN IN NITROGENOUS FERTILIZER MATERIALS

The price of the nitrogen in ammonium sulfate was formerly largely determined by the price set for the nitrogen in sodium nitrate or Chile saltpeter. With the successful establishment of the synthetic nitrogen industry in recent years, the cost of nitrogen has been greatly reduced. The decided influence of synthetically produced nitrogenous products in decreasing the cost of nitrogen is shown in table 2, which compares the wholesale prices of a number of nitrogenous fertilizer materials since 1885.

Table 2.—*Wholesale prices of a unit (20 pounds) of nitrogen in fertilizer materials in stated years*

Year	Sodium nitrate	Ammonium sulfate	Anhydrous ammonia	Calcium cyanamide	Year	Sodium nitrate	Ammonium sulfate	Anhydrous ammonia	Calcium cyanamide
1885	$2.75	$3.03			1931	$2.36	$1.34	$1.36	$1.38
1890	2.33	3.18			1932	1.86	1.02	1.34	1.08
1895	2.36	2.75			1933	1.53	1.12	1.15	1.13
1900	2.37	2.79			1934	1.54	1.18	1.09	1.20
1905	2.97	3.01			1935	1.47	1.13	1.09	1.20
1910	2.76	2.64		$3.43	1936	1.55	1.17	1.09	1.21
1915	3.04	3.09		2.54	1937	1.64	1.32	1.09	1.26
1920	4.44	4.08		3.40	1938	1.68	1.36	1.09	1.29
1925	3.28	2.65		2.20	1939	1.68	1.33	1.09	1.16
1930	2.49	1.79	1.40	1.65					

AMMONIUM SULFATE IN RELATION TO CROP PRODUCTION

Nitrogen an Essential Plant-Food Element

The growth of plants is vitally concerned with nitrogen, a number of its compounds playing an important part in plant nutrition. Without enough available nitrogen in the soil, plants are apt to possess foliage of a pale color, are likely to become stunted in growth, and fail to produce satisfactorily. Nitrogen is a growth-promoting element and its effect generally is to give the plant a good start, which enables it to utilize other available nutrient materials advantageously and to reach maturity in much better condition than with a low nitrogen supply. Although all arable soils contain some available nitrogen, frequently the supply is considerably below the needs of the growing crop, especially during early growth when an ample supply is very important.

Plants utilize nitrogen in different forms of combination including ammonium, nitrite, nitrate, and organic compounds. The ammoniacal, nitrite, and organic forms are to a considerable extent eventually changed over to nitrate nitrogen through the action of soil organisms. It is recognized that ammoniacal nitrogen can be directly utilized by plants, although it is utilized by some plants to a much greater extent than by others, without first undergoing change to the nitrate form. This appears to be true also of the nitrogen of certain organic nitrogenous compounds and of nitrites even, although much less so than with either the ammoniacal or nitrate form. The opinion that nitrogen has to be in the nitrate form to be utilized by plants is by no means true. This opinion has gained some support from the fact that analytical examination shows that comparatively slight amounts of ammonium or nitrite compounds are present in soils. That nitrates exceed them is well recognized, but it is entirely conceivable that during the transition period of organic nitrogen—to ammonium compounds, to nitrites, to nitrates—certain water-soluble organic nitrogenous compounds, ammonium compounds, and even nitrites are absorbed by plants and utilized in plant metabolism.

Ammonia is constantly being formed in soils as the result of the action of ammonifying bacteria on soil organic matter, the rate of formation depending largely upon moisture supply, soil temperature, and soil reaction. Although the measurable amount of ammonia so formed will be found to be not very large, normally only a few pounds per acre of soil, nevertheless the reason for this may be due in part to utilization by soil bacteria and the crop.

Fertilizer studies under field conditions with cotton, potatoes, and other crops indicate no superiority of nitrate nitrogen over ammoniacal nitrogen when it comes to crop yield and quality, especially when the soil is nearly neutral or when the fertilizer mixture is made non-acid-forming by the appropriate addition of limestone. Recent field experiments indicate that the nitrate nitrogen has a tendency to be better under low pH or acid conditions and the ammonia nitrogen to be the more efficient under a high pH; that is, slight acidity or alkalinity of the soil. As a matter of fact, such studies have generally shown that best results are obtained when both forms of nitrogen are used together as sources of nitrogen in fertilizer mixtures.

Properties of Ammonium Sulfate in Relation to the Soil

Ammonium sulfate is readily soluble in water and is a source of nitrogen quickly available for plants. It is now considered quite as available as sodium nitrate if the soil is maintained nearly neutral, and is more immediately available than such organic sources of nitrogen as fish scrap, cottonseed meal, tankage, and similar materials. In many mixed fertilizers different carriers of nitrogen are used so as to provide a somewhat continuous action to maintain the growth of the crop.

Although ammonium sulfate and sodium nitrate both are readily soluble, the ammonium compound does not leach from the soil as rapidly as the nitrate and may therefore be expected to give better results in wet seasons. The greater retentiveness of ammonium sulfate by the soil is primarily due to the fact that ammonium compounds react more effectively with certain soil constituents whereby they are rendered less soluble or "fixed" in the soil. In general, such reactions are more pronounced as the soil becomes more complex with respect to its collodial content, chiefly clay particles.

The use of ammonium sulfate, or of other ammonium salts, tends to increase soil acidity. This effect will be fairly proportionate to the amount of ammonium sulfate that has been applied but will depend to some extent on the nature of the soil.

The development of soil acidity from the use of ammonium compounds is brought about by soil bacteria, commonly called nitrifiers, that are able to convert the ammonia in ammonium sulfate to nitric acid, leaving also a residue of sulfuric acid. Both are strong mineral acids and will react with basic constituents of the soil, chiefly lime and magnesia, to form the respective nitrates and sulfates. These compounds, particularly the nitrates, are subject to loss through leaching. Thus the continuous use of ammonium sulfate will deplete the soil of its bases and thereby gradually create a more intense degree of soil acidity.

This acid-producing effect, however, may be counteracted in two ways, (1) by applying a liming material to the soil, or (2) by adding some form of finely ground limestone to the fertilizer mixture. As a matter of fact the present generally accepted practice is to add sufficient finely ground limestone (usually dolomitic) to the fertilizer mixture to offset the acid-forming tendency of any fertilizer material that is present, including ammonium sulfate. This procedure insures a fertilizer mixture of a potentially neutral reaction and is one that has been largely adopted by the fertilizer industry. By this means the value of ammonium sulfate has been considerably enhanced and its use more than ever justified as a source of nitrogen in fertilizer mixtures.

In cases where ammonium sulfate is applied individually for top dressing the use of approximately 125 pounds of ground limestone for each 100 pounds of ammonium sulfate applied to the soil has been recommended to counteract the acidity formed.

Residual Effects of Ammonium Sulfate on Crop Growth

The quick availability of the nitrogen of ammonium sulfate to plants implies little residual effect from this fertilizer material on crops after the first season. It may, however, under some conditions so stimulate plant growth during its first season of application that the increased plant residues thus given to the soil will continue its effect on succeeding crops. The long-continued use of ammonium sulfate will affect most crops adversely unless provision is made for proper control of the soil acidity developed. Crops such as potatoes, corn, and wheat will prove to be more tolerant to the continued use of fertilizers containing ammonium sulfate than would be expected of alfalfa or red clover.

Agricultural Uses of Ammonium Sulfate

The principal ways of using ammonium sulfate from a crop-production and fertilizer standpoint are (1) the preparation of commercial fertilizers, (2) direct application to the soil as side dressing, (3) home mixing, and (4) special uses such as the production of greenhouse crops, the preparation of composts from farm and household wastes, and dissolved in water as a means of stimulating the growth of various plants. The greatest use of ammonium sulfate is in the production of commercial fertilizers.

Application to Soil

Ammonium sulfate is very soluble and large amounts should not be applied at one time, as any excess not used by plants may be lost by leaching, particularly if the soil is an open sandy one. In this connection it has been found that losses of nitrogen by leaching are not so serious with ammonium sulfate as with sodium nitrate. If a large amount of ammonium sulfate is to be used it will be found more economical to apply it in divided applications at intervals sufficient to allow the plants to use up the fertilizer. Like other highly soluble materials care needs to be exercised when applying ammonium sulfate in order to avoid crop injury either at the germination period or to subsequent plant growth. Proper placement of ammonium sulfate to avoid contact with the seed or plant will obviate injurious action.

In the production of commercial fertilizers the inclusion of several nitrogen sources is frequently considered to be a good practice. For immediate availability nitrate nitrogen, chiefly as sodium nitrate and, to a less extent, potassium nitrate, Cal-Nitro, calcium nitrate, etc., are used, and for both immediate and continuing action ammonium sulfate, urea, or other nitrogenous material is used.[2] Any need for nitrogen later in the growing crop season can be met, if commercially practicable, by the use of one of the organic nitrogen byproduct materials, such as fish scrap, cottonseed meal, tankage, or castor pomace.

---

[2] Other nitrogenous materials would include calcium cyanamide and different nitrogen liquors.

The quantity of ammonium sulfate to be applied to crops varies with so many conditions that it is difficult to make any general recommendation. Considering its price in relation to the products grown, it will normally pay to use only from 50 to 150 pounds an acre for general farm crops, but for special crops larger quantities may be used to advantage. The quantity to use depends not only on the type of soil and of crop grown but also on the previous treatment of the soil and the amount of manure or compost that is available.

In the early spring, in sections where the soil is apt to be cold and nitrification retarded, applications of quickly available nitrogen are often made to tide the crop over such periods. Both sodium nitrate and ammonium sulfate are used to furnish available nitrogen, the quicker availability of the former being offset to some extent by the fact that the soil retains ammonium sulfate more effectively than it does sodium nitrate. After the soil warms up, the action of ammonium sulfate is speeded up. In sections where the soil warms up more quickly there is very little choice between the two materials. Its greater nitrogen concentration and generally lower cost per pound of nitrogen are factors favorable to ammonium sulfate. Approximately 80 pounds of ammonium sulfate will be the equivalent of 100 pounds of sodium nitrate with respect to nitrogen.

The relation of these two nitrogenous materials to soil reaction should be given primary consideration by the farmer or horticulturist. Where the soil is alkaline or even slightly acid satisfactory growth is to be expected in the case of most crops from the use of ammonium sulphate. In the case of other crops, such as potatoes and strawberries, it has been found to be beneficial even under more acid conditions. If the soil is strongly acid, pH 5.0 down to 4.5, the use of nitrate nitrogen is indicated, although any soil so acid, except for a few special crops, should be limed to at least partially counteract this acid condition.

It should be considered that an excess of a soluble nitrogenous fertilizer applied at the wrong time will often delay maturity of the crop and as a result may do more harm than good.

Soil Bacteria

The application of ammonium sulphate influences the bacterial flora of the soil primarily in two ways: (1) The soluble nitrogen furnishes food for the bacteria; and (2) the increase in soil acidity reflects itself in the numbers and kinds of bacteria, particularly if the ammonium sulfate is used more or less continuously. When a large amount of an organic material, such as straw, is turned under, the addition of ammonium sulfate to the soil to furnish a source of available nitrogen for the bacteria that are instrumental in breaking down the straw is a good practice. Otherwise the bacteria would compete with the crop for any available nitrogen in the soil. Liming, if required, would have to be considered too.

Ammonium Sulfate in Mixtures

Ammonium sulfate may be used to advantage as an individual material to stimulate plant growth. It no doubt, however, is best utilized when mixed with carriers of phosphoric acid and potash and other needed elements to form a complete plant-food mixture. Because ammonium sulfate is a cheap source of nitrogen it is one of the most widely used materials in fertilizer mixtures. A complete mixed fertilizer may be formulated from several materials carrying its nitrogen in part from nitrate of soda, in part from ammonium sulfate, and in part from some organic source. A generation ago this tended approximately to be one-third from nitrate, one-third from sulfate, and one-third from organic. In recent years, however, the tendency has been to cut down both the nitrate and organic sources and increase the proportion of ammonium compounds, particularly ammonium sulfate. There are other satisfactory sources of nitrogen that may be used in the formulation of mixed fertilizer if their cost is right. Where the State fertilizer control does not compel the statement of the materials and amounts of each in the fertilizer mixture, there will naturally be a tendency among manufacturers to use as cheap materials as are available and reasonably satisfactory, so long as they will pass the fertilizer-control laws.

Proper Use of Ammonium Sulfate

It should be understood that there are certain points to be considered in the use of ammonium sulfate and other nitrogenous fertilizer materials. Too much nitrogen may delay maturity and may force leaf growth at the expense of the quantity of seed or fruit. If too great quantities are applied to fruit trees late in the season, succulent growth may be formed that will not be able successfully to withstand winter conditions. There is also the danger of injuring the carrying qualities of certain fruits and vegetables. When applying fertilizer salts, such as ammonium sulfate or sodium nitrate, certain precautions are essential to avoid crop injury. In top dressing vegetable crops with ammonium sulfate, it may be advisable to mix it or dilute it with some inert material, such as dry sand or earth.

Methods of Applying Ammonium Sulfate

Ammonium sulfate may be applied by hand over small areas, but for any large area a fertilizer distributor will prove more satisfactory. Special attachments to planters and cultivators are sometimes used. Probably the use of soluble fertilizers in solution or in irrigation water insures the most even distribution. At present the latter method is largely limited to greenhouse culture, although if desirable its use may be extended.

In applying ammonium sulfate to fruit trees a convenient method is to measure the material by volume. Small pails of some description serve well for this purpose. By marking each pail conspicuously on the inside to indicate the quantity per tree, each worker can be furnished a pail and mistakes thus avoided. If 8 pounds of ammonium sulfate are to be applied per tree the material can be poured into pails marked in accordance with this quantity. If trees in other sections of the orchard are to receive a different quantity the pails can be marked accordingly. In making the application, most of the material should be spread broadcast in a broad ring under the outer spread of branches. As ammonium sulfate is soluble in water it may be left for the rainfall to wash into the soil.

Use on Individual Crops

In addition to the application of a balanced fertilizer before planting, it is a common practice to side dress the cotton crop about the time it is chopped with a quickly available nitrogenous fertilizer. Ammonium sulfate may be used at the average rate of about 100 pounds per acre.

Ammonium sulfate may be used in the spring as a top dressing on fall-sown small grains at the rate of about 75 pounds per acre. This is considered to be a good practice when the grain has come through the winter showing pale foliage. A dose of available nitrogen in the early spring helps to restore normal growth conditions.

In the Southeastern States, an application of ammonium sulfate on corn before the last cultivation may be made at the rate of 100 to 150 pounds per acre, although even higher amounts have been used.

Ammonium sulfate has been found to be satisfactory as one of the sources of nitrogen in mixed fertilizers for use on tobacco. One-third of the nitrogen may be derived from ammonium sulfate, the remainder equally from nitrate and organic nitrogen sources, including urea. The latter fertilizer material, however, is classified by cooperating agencies studying the fertilizer requirements of tobacco as occupying the same status as ammonium sulfate. For tobacco seedbeds a complete fertilizer containing some ammonium sulfate is applied before planting, and later a solution of ammonium sulfate may be applied to stimulate the growth of seedlings.

Ammonium sulfate, as well as other quickly available nitrogen materials, is widely used on fruit trees, especially apples. The amount of ammonium sulfate to use, and whether phosphoric acid and potash should also be used, will depend on many factors, such as nature of the soil, its reaction, its cultivation, and the use of cover crops or sod. The following amounts of ammonium sulfate, if used as a quickly available nitrogen source in orchards, have been recommended for annual application to apple trees: 0.25 pound on 1 and 2-year-old trees, 0.5 to 0.75 pound on 3-year-old trees, 1.5 to 3.25 pounds on 6- to 10-year-old trees, and 4 to 8 pounds on 15- to 30-year-old trees. These amounts are given only as a general guide and must be modified to suit various conditions, such as soil type and vigor of tree.

It should be considered that if orchards are being grown in nonlegume sods the rate should usually be about the maximum amounts indicated, whereas under cultivation the minimum amounts should prove sufficient. Ammonium sulfate is usually applied in early spring, about 2 weeks before the blooming period.

The relative efficiency of ammonium sulfate as a source of nitrogen for plants, including fruit trees, depends on the reaction of the soil or nutrient medium. If the reaction of the soil, designated pH, is properly controlled so as to provide a slightly acid to alkaline reaction, ammonium sulfate has been shown to be equally as available as sodium nitrate. On the other hand, if the reaction of the soil is allowed to become strongly acid, the efficiency of ammonium sulfate as a source of nitrogen for different crops is reduced.

Continued use of ammonium sulfate may prove injurious to clover or other legume sod in the orchard, but this effect can be avoided by liming, by using sodium nitrate alternately, or by applying a properly proportioned mixture of ammonium sulfate and sodium nitrate. Used properly these nitrogenous materials usually give equally good results. The choice between the use of these nitrogen carriers in fruit orchards will depend largely upon their cost in terms of nitrogen units, bearing in mind that eventually liming will be required if ammonium sulfate is used continuously. As fertilization is only one of the factors to be considered in fruit production, and the use of fertilizers is so closely related to proper methods of pruning, cultivating, spraying and other practices, careful study of the orchard should be made before fertilizers are applied, and the State agricultural experiment station horticulturists and the county agents, who have knowledge of local conditions, should be consulted.[3]

Quality of Crops

In addition to its action in increasing yields ammonium sulfate is used to influence the quality of crops. Crops grown quickly with an ample supply of available nitrogen may be more tender and have a better color. This especially applies to leafy vegetables, such as kale, lettuce, and spinach. When the crop is to be shipped, too much nitrogen may produce a product that will not transport well. In orchards, care needs to be exercised in the use of nitrogen, because if too much is used the quality of fruit is likely to be lowered due to lack of good color development. Application of ammonium sulfate to meadows and pastures has been found not only to improve the yield but also to increase the protein content of the crop. A similar increase of protein content was found in wheat.

Use in Gardens

In making surface applications, ammonium sulfate should not be applied too near the growing plant, and it should not be allowed to touch the foliage or stems of the plant, especially when wet, as serious injury to the tissue may result. After the ammonium sulfate has been applied it should be worked lightly into the surface soil. When the first rainfall comes it will be dissolved and distributed throughout the soil. Generally it will be advisable to make several light applications instead of one heavy dressing.

Ammonium sulfate is especially useful for spring applications to crops needing an early start. It will have a tendency to delay maturity if applied late in the growing season. Crops, such as lettuce, early cabbage, and spinach, are benefited by early applications of ammonium sulfate, especially those that are eaten raw or as salads and in general those in which rapid growth insuring succulence is desirable.

---

[3] Excellent fertilizer studies with both mixed fertilizers and individual nitrogenous materials have been conducted by a number of the State agricultural experiment stations and results obtained have been issued in various publications. With some of these stations the Bureau of Plant Industry, U. S. Department of Agriculture, is conducting cooperative studies on the effect of fertilizer on fruit production and quality.

Ammonium sulfate, in addition to furnishing nitrogen, also supplies sulfur to crops. In general, it is desirable to use phosphoric acid and potash in conjunction with nitrogen for garden or truck crops. Examples of mixtures of this character are given in the following pages.

SPECIAL USES FOR AMMONIUM SULFATE

For Greenhouse Crops

Ammonium sulfate is used in solution, especially among florists and vegetable growers producing under glass. One ounce of ammonium sulfate dissolved in 2.5 gallons of water has been found a good strength to use to supply available nitrogen quickly. The amount of solution to use in a given case will depend largely upon the soil and its reaction, the crop grown, and its age. In the production of azaleas, rhododendrons, and most evergreen shrubs where suitable soil acidity is a factor in promoting optimum growth such a solution may be used to advantage.

For Lawns

Ammonium sulfate, 5 pounds diluted with 15 pounds of cottonseed meal, or similar organic byproduct material, makes a good early spring lawn treatment, providing the grass with a supply of quickly available nitrogen at a time when nitrification is at a low ebb. This quantity will do for 2,000 square feet of lawn area. Following its application the mixture should be watered in well, or it should be applied before a rainfall.

Home Mixing

Ammonium sulfate is a standard fertilizer material and therefore is suitable for use in the preparation of home mixtures, as it is usually obtainable in a good mechanical condition from practically all agencies in the fertilizer trade. The following formulas, using ammonium sulfate as a partial source of nitrogen for home mixing, are given as examples:

Mixture 1 (5–10–5)[4]

	Pounds
Nitrate of soda (16.0 percent N)	200
Sulfate of ammonia (20.5 percent N)	200
Tankage (7.5 percent N)	400
Superphosphate (20.0 percent P_2O_5)	1,000
Muriate of potash (50 percent K_2O)	200
Total	2,000

This fertilizer formula has been used for vegetables.

---

[4] Percentages, respectively, of nitrogen, phosphoric acid, and potash.

Mixture 2 (6–8–4)

	Pounds
Nitrate of soda (16 percent N)	313
Ammonium sulfate (20.5 percent N)	300
Cottonseed meal (7 percent N)	143
Superphosphate (20 percent P_2O_5)	800
Potassium chloride (50 percent K_2O)	160
Pulverized dolomitic limestone	284
Total	2,000

This mixture has been suggested for cotton. One-half the nitrogen is from ammonium sulfate. The dolomitic limestone and the nitrate of soda will offset any tendency for the mixture to cause acidity.

Mixture 3 (4–12–4)

	Pounds
Urea (42 percent N)	48
Ammonium sulfate (20.5 percent N)	300
Superphosphate (20 percent P_2O_5)	1,200
Potassium chloride (50 percent K_2O)	160
Pulverized dolomitic limestone	292
Total	2,000

This fertilizer mixture, relatively high in phosphoric acid, has been recommended for small grains, pasture, etc.

Mixture 4 (7–6–5)

	Pounds
Nitrate of soda (16 percent N)	375
Sulfate of ammonia (20.5 percent N)	300
Cottonseed meal (7 percent N)	285
Superphosphate (20 percent P_2O_5)	600
Potassium chloride (50 percent K_2O)	200
Pulverized dolomitic limestone	240
Total	2,000

This mixture is often used for early potatoes and truck crops on sandy soils in the eastern trucking regions. It is high in available nitrogen. It will only slightly increase soil acidity. On heavier soils, especially where manure or leguminous cover crops have been used, less nitrogen may be needed and a 6–6–5 or a 5–7–5 fertilizer mixture may be more economical.

Mixture 5 (5–8–7)

	Pounds
Nitrate of soda (16 percent N)	150
Sulfate of ammonia (20.5 percent N)	300
Fish scrap or tankage (8 percent N)	150
Superphospate (18 percent P_2O_5)	890
Potassium chloride (50 percent K_2O)	280
Pulverized dolomitic limestone	230
Total	2,000

This mixture could be used as a fertilizer for main crop potatoes. The dolomitic limestone will not only be useful in neutralizing the acid effects of the ammonium sulfate but will also supply magnesium, which is often necessary for optimum growth.

On soils high in humus more potash may be necessary and each additional 40 pounds of 50 percent potassium chloride will increase the percentage of potash 1 percent. If a 5–8–10 mixture is desired use 400 pounds of potassium chloride instead of the 280 pounds given and reduce the filler by 120 pounds to 110 pounds. It is recommended that a filler that has some plant-food value, such as dried peat or ground rock phosphate, be used.

Mixture 6 (4–10–8)

	Pounds
Nitrate of soda (16 percent N)	125
Sulfate of ammonia (20.5 percent N)	190
Cottonseed meal (7 percent N)	300
Superphosphate (20 percent P_2O_5)	1,000
Potassium chloride (50 percent K_2O)	320
Filler	65
Total	2,000

This mixture has been recommended for sweetpotatoes, especially on soils of lighter texture, such as sands or sandy loams.

Mixture 7 (5–5–5)

	Pounds
Ammonium sulfate	200
Cottonseed meal (7 percent N)	856
Granulated peat (acid reaction)	244
Superphosphate (20 percent P_2O_5)	500
Potassium sulfate (50 percent K_2O)	200
Total	2,000

This mixture increases soil acidity and may be used on plants that do best on acid soil, such as azaleas, rhododendrons, and laurel. The peat used should be acid in reaction. This mixture will keep the soil acid, but if acidification of the soil is the prime consideration this may be accomplished while preparing the soil for the plants. Aluminum sulfate, sulfur, and tannic acid may be added for this purpose. In any event it is best when plants that prefer acid soils are grown to test the soil at regular intervals to ascertain its reaction.

If only a small amount of fertilizer is needed it is easy to mix up any required amount, such as one-twentieth or one-tenth of any of the quantities give above.

Preparation of Composts From Waste Materials

In maintaining soil fertility it is very necessary to add organic matter periodically. The general farmer normally relies on animal manures and green-manure crops. On small farms and suburban places these methods may not be satisfactory, because the lack of farm animals or the high price of land, and the small acreage makes the use of green manures uneconomical. In such cases the use of composts may prove to be a useful substitute, as it enables the farmer or gardener to use available and cheap products, such as leaves, straw, muck, peat, soot, trade and kitchen wastes. Rotting of these materials by themselves will ultimately make a satisfactory compost, but the process may be hastened by the addition of chemicals and water. Besides hastening the decomposition of the waste products the chemicals add to the plant-food value of the compost.

The New York Agricultural Experiment Station at Geneva, N. Y., recommends that to each ton of dry straw the following fertilizer materials be added:

	Pounds
Sulfate of ammonia	60
Ground limestone	50
Superphosphate	30
Muriate of potash (potassium chloride)	25
Total	165

The straw or other organic matter is spread out in a pile, layer by layer. Each 6-inch layer is treated with the chemicals. The pile is built up layer by layer until it is about 4 feet high. Each layer is wet as placed, and finally the pile is kept moist as decomposition occurs. In warm weather a compost of this character should be thoroughly decomposed in a few months.

The Missouri Agricultural Experiment Station recommends a mixture consisting of 45 percent of ammonium sulfate, 40 of finely ground limestone, and 15 of ordinary superphosphate. This mixture may be used at the rate of 150 pounds per ton of straw or other waste organic matter.

The Iowa Agricultural Experiment Station uses two mixtures—one consisting of 45 percent of ammonium sulfate, 23 of finely ground rock phosphate, and 32 of finely ground limestone; and the other of 45 percent of ammonium sulfate, 15 of superphosphate (16-percent grade), and 40 of finely ground limestone. Both these mixtures proved satisfactory when sufficient water was added.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS LAST PRINTED

Secretary of Agriculture	Claude R. Wickard.
Under Secretary	Paul H. Appleby.
Assistant Secretary	Grover B. Hill.
Director of Information	M. S. Eisenhower.
Director of Extension Work	M. L. Wilson.
Director of Finance	W. A. Jump.
Director of Personnel	Roy F. Hendrickson.
Director of Research	James T. Jardine.
Director of Marketing	Milo R. Perkins.
Solicitor	Mastin G. White.
Land Use Coordinator	M. S. Eisenhower.
Office of Plant and Operations	Arthur B. Thatcher, *Chief.*
Office of C. C. C. Activities	Fred W. Morrell, *Chief.*
Office of Experiment Stations	James T. Jardine, *Chief.*
Office of Foreign Agricultural Relations	Leslie A. Wheeler, *Director.*
Agricultural Adjustment Administration	R. M. Evans, *Administrator.*
Bureau of Agricultural Chemistry and Engineering.	Henry G. Knight, *Chief.*
Bureau of Agricultural Economics	H. R. Tolley, *Chief.*
Agricultural Marketing Service	C. W. Kitchen, *Chief.*
Bureau of Animal Industry	John R. Mohler, *Chief.*
Commodity Credit Corporation	Carl B. Robbins, *President.*
Commodity Exchange Administration	Joseph M. Mehl, *Chief.*
Bureau of Dairy Industry	O. E. Reed, *Chief.*
Bureau of Entomology and Plant Quarantine	Lee A. Strong, *Chief.*
Farm Credit Administration	A. G. Black, *Governor.*
Farm Security Administration	C. B. Baldwin, *Administrator.*
Federal Crop Insurance Corporation	Leroy K. Smith, *Manager.*
Forest Service	Earle H. Clapp, *Acting Chief.*
Bureau of Home Economics	Louise Stanley, *Chief.*
Library	Claribel R. Barnett, *Librarian.*
Bureau of Plant Industry	E. C. Auchter, *Chief.*
Rural Electrification Administration	Harry Slattery, *Administrator.*
Soil Conservation Service	H. H. Bennett, *Chief.*
Surplus Marketing Administration	Milo R. Perkins, *Administrator.*

This circular is a contribution from

Bureau of Plant Industry	E. C. Auchter, *Chief.*
Division of Soil Fertility Investigations	Oswald Schreiner, *Principal Biochemist, in Charge.*
Division of Fertilizer Research	R. O. E. Davis, *Senior Chemist, Acting in Charge.*

U. S. GOVERNMENT PRINTING OFFICE: 1940

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - - Price 5 cents